can lead to more positive relations between commodity production and recreation, making them complementary rather than competitive. Better identification of key recreation values and sites is one essential element of more effective integration among uses.

More Stable Use?

Many types of outdoor recreation are growing more slowly than in the past. Hunting, fishing, wilderness use, and many other activities appear to have plateaued after decades of rapid growth. Newer activities, such as snowmobiling, cross-country skiing, and hang gliding, grew very rapidly at first but now have leveled off. Changing population and social structure suggest that recreational use in the future may be more stable than in the past.

If use stabilizes, managers will have an opportunity to solve important problems and make progress rather than just struggling to keep up with escalating patterns of use. Some new activities, however, probably will develop to surprise us.

Visitor Expectations Higher

The number of recreationists may not be skyrocketing in the future, but visitors are likely to be more discriminating. Their expectations for quality are likely to change and generally become higher, as the average visitor becomes more experienced and committed. Most types of use will still grow, although more slowly than in recent years.

Continuing substantial use by visitors seeking quality experiences will provide managers of recreation and wilderness in future forests with a difficult challenge. Meeting it successfully will require continuing advances in scientific knowledge and technology.

Protecting Forest Resources From Disease

Harry R. Powers, Jr., *chief research plant pathologist, Forestry Sciences Laboratory, Forest Services, Athens, GA*

Nations that fail to protect their forests risk serious economic and social consequences. That is why conservationists work hard to protect forests from overexploitation and unwise use.

Many people do not know, however, that forest tree diseases can be even more devastating than misuse. Diseases carelessly introduced from Europe and Asia have caused billions of dollars of lost revenue from America's forests, and modern forest-management practices have worsened the impact of some of our native tree diseases. Perhaps the worst examples of introduced diseases are chestnut blight and white pine blister rust, which were brought into the United States around the turn of the century. The former destroyed our most valuable native hardwood species, and the latter decimated white pine stands from New England to the Pacific Northwest. Before the advent of high-yield plantation forestry, fusiform rust of southern pines was not much of a problem. Now it is causing over $128 million a year in damage to southern forests.

Costs Must Be Low

The devastation of forest diseases is easy to recognize; the appropriate corrective action is less apparent. Although a forest may be worth a great deal, each individual tree in it is worth little. Even in the South, where trees grow very rapidly, it takes 25 years for a pine to reach pulpwood size and 35 years or more to reach sawtimber size. In the West, trees in managed forests typically are harvested when they are 80 to 120 years old. These are years of waiting for returns on investment. They are also years during which the trees are at risk from disease and insect attack.

How can our forests be protected from diseases at a reasonable cost? Years ago foresters came to the scientific community with that question. The research has been long and difficult, but answers are emerging. The answers will be somewhat different for each disease, but often they will include some tree breeding for disease resistance. Chemical treatments in forest situations are not economically feasible: the individual trees just aren't worth that kind of investment. Yet, as a group, those planted trees represent much of the Nation's timber supply for the 21st century.

Most of the economically important diseases of forest trees are caused by fungi, and trees often vary in their resistance to infection and damage by these fungi. Breeding of trees for disease resistance has proven practical for some diseases, particularly the rust diseases that produce cankers on stems and branches. As knowledge of the genetics of hosts and pathogens (disease-causing agents) increases, the number of diseases that can be controlled in this manner is likely to increase.

Breeding for resistance to tree diseases is most advanced in loblolly and slash pines, the two most commonly planted tree species in the Southern United States. The purpose has been to reduce the devastation of fusiform rust. In the next century, the experiences with these species and this disease are likely to be repeated for other trees and other diseases, so a review of progress with these southern pines is instructive.

Progress With Fusiform Rust

The fusiform rust fungus spends part of its life on oaks and part on southern pines. In the spring, spores produced on oak leaves are released in huge numbers. When such a spore alights on young, succulent new growth of a pine, an infection results that develops into perennial galls or cankers. These attacks are most damaging on pines less than 10 years of age. Fusiform rust deforms stems and kills trees, causing huge economic losses. Infections also occur on older trees, but the results are not as serious.

Although fusiform rust has always been around, it was little more than a nuisance before 1950. Now its effects have reached epidemic proportions in parts of Alabama, Georgia, Florida, Mississippi, and South Carolina. Entire pine plantations are often destroyed, and the risk of newly planted seedlings becoming infected has increased steadily for many years.

Why the increase? The culture of loblolly and slash pines in the South has proven to be profitable, and millions of acres of intensively managed plantations have been established. Unfortunately, the conditions that are ideal for the rapid growth of these pines in single-species plantings also appear to be ideal for the spread of the disease.

Programs for the genetic improvement of pine seedlings for reforestation were begun in the 1950's, before the rust threat was recognized. Rust resistance was not a major factor in the selection of superior trees at that time. As a result, the first superior pines made available for reforestation in the South usually were not superior in their resistance to fusiform rust.

By the late 1960's, increasing damage from rust became apparent, and research on the problem was accelerated. Cereal rusts, caused by a similar fungus, are controlled almost entirely through breeding of resistant strains of wheat, oats, and barley. The same approach appeared possible for pines. The first order of business was to develop a system for rapidly testing the rust resistance of large numbers of seedlings under standardized conditions. Satisfactory techniques for artificial inoculation were developed, and a reliable system was operational within 5 years. Now almost all loblolly and slash pines that have been selected for superior traits of all sorts have been tested for their ability to produce rust-resistant offspring.

Fungi Adapt

Results of artificial inoculations also taught us much about the rust fungus. The fungus is highly variable in its ability to cause disease on different pine selections. An individual pine selection often is resistant to some races of the fungus but not to others. Races of the rust from different geographic areas vary in their ability to cause disease. This information helps to determine which pine seed sources to plant in specific areas.

The great variation was no surprise. It also occurs in the wheat rust fungus. Nevertheless, it is bad news for foresters. It means that no single form of resistance can be relied on for a long time over a large area. Seedlings with such resistance will be protected for the first few critical years after planting. But within a few years, a new strain of the fungus is likely to emerge with the ability to overcome the factor for resistance. Once this strain develops, additional seedlings of that type planted in the area will no longer be resistant. That is what happened to a strain of sugar pine selected and planted for its resistance to white pine blister rust in the Pacific Northwest. In resistance research and development work, plant pathologists must work with two biological systems—the fungal pathogen and the pine host.

Types of Resistance

Large-scale efforts are being made to locate as many new resistant trees as possible. Several different forms of resistance have already been found. One type seems to prevent the rapid spread of the fungus from a needle or branch into the main stem. A second form of resistance occurs when the fungus is walled off by dead host cells after infection takes place. Research is under way to discover other resistance mechanisms to include in breeding programs.

When the forms of resistance of pines and the types of virulence of the fungus are understood, planting strategies can be developed. In the next century, pathologists will deploy resistant strains of trees as generals deploy troops for a battle. By constantly developing new strains of pines and by deploying them to best advantage, it will be possible to stay a step or two ahead of the rust fungus.

To do so, the process for getting some forms of resistance into the genes of seedlings used for reforestation must be speeded. At present, that process takes up to 15 years in pines; to cut that down to 5 years will not be easy. Remember that in breeding, disease resistance is only one of many desirable traits to improve. Growth rate, stem form, wood properties, and other characteristics may be equally important.

Tissue culture is one promising technique for speeding the improvement process. Tissue culture makes it possible to develop large numbers of clonal plantlets without going through the normal reproductive cycle. Another technique, enzyme analysis, may enable us to detect resistance in a tree in few days instead of the 1 to 5 years needed with cur-

L. D. Dwinell, FS

Tree breakage and death are common after fusiform rust infection sweeps through a stand. This 14-year old slash pine plantation shows heavy damage.

rent techniques. Gene splicing is another promising approach, but there is much to learn before fully using the techniques of new biotechnology.

At present, the planting of resistant trees is our first line of defense against fusiform rust in pine plantations. Strains of loblolly and slash pine now producing seeds in a rust-resistant seed orchard in Georgia have reduced fusiform rust incidence by 50 percent in experimental plantings. Seedlings from this orchard are now being sold to private landowners and being planted over large areas. Additional breeding promises to reduce rust incidence by 75 percent, which will make reforestation investments attractive again in areas where the rust hazard is high.

Using Chemicals

Fungicides have seldom been used to control diseases in forests, not because they were ineffective but because treatment costs have exceeded the value of the potential benefits. That situation may change in the years ahead. The value of forest products has been rising and will contiue to rise. At the same time, the effectiveness of treatments has been increasing. Eventually, treatment of diseases in the forest may become common, as it is now in fruit orchards.

For years, fungicides have been used to control diseases in forest tree nurseries, where millions of the trees are grown on a few acres. New compounds are increasing the effectiveness of these treatments. For example, a recently developed systemic fungicide has proven effective for rust control in nurseries.

Formerly, rust infections were prevented with topical sprays. To be effective, these sprays had to cover the entire surface of susceptible plants. To maintain protection during the entire spring rust-infection period, seedlings had to be sprayed 35 to 40 times.

Systemic fungicides are absorbed by the plant and move through all tissues, providing protection for tissues formed after they are applied. Unfortunately, currently available systemics are effective for only a few weeks after application. Even so, 3 or 4 systemic applications take the place of up to 40 topical sprays, and they are even more effective.

Research indicates that systemics also might be used to protect seedlings for up to 1 year after planting. In the next few years, new systemic formulations may be developed that will protect seedlings for the first few critical years after planting.

Protecting Investments

Until the 20th century, Americans paid little attention to the health of their forests. They took what they needed and gave nothing in return, worrying little about how diseases might be lowering yields. That attitude has changed drastically.

Over the past 40 years, high-yield plantation forestry has developed in the South and the Pacific Northwest to provide the wood and fiber that our lifestyle demands. Intensive forestry, including planting of huge acreages with a single species on well-prepared sites, is necessary to produce the timber needed. In such plantings, however, the risk of disease losses is high, and the losses are more costly because of increasing timber values. The 21st century will see more intense forest management, because of the need to produce more and more wood on a shrinking land base.

In the 21st century, there will be increasing numbers of forest disease problems. As plantation forestry spreads, some diseases now thought of as minor may become major enemies. You can be sure, however, that researchers will be fighting tree diseases harder than ever and using new technologies as fast as they are made available. This Nation cannot afford to share our forest yields with fungi.

Protecting Future Forests From Insects

William J. Mattson, *principal insect ecologist, North Central Forest Experiment Station, Forest Service, East Lansing, MI*

Protecting our world's future forests from insects may be far more important than it is today because burgeoning world populations will place much greater demands on forests for both recreation and raw materials. As a result, a unit of loss to insects in these more precious forests will be far more costly to society than today.

To combat future insect problems, innovative insect management methodology that stresses prevention rather than cure, and, at the same time, is inexpensive, long lasting, and environmentally safe must be developed. Future research on forest insects will focus on:

- Developing and enhancing inherent plant resistance.
- Deploying resistant plant varieties in a manner that minimizes the evolution of adaptations by insects to overcome resistance.
- Employing sophisticated integrated pest-management strategies that more effectively use inherent plant resistance, natural enemies, pesticides-biocides, and behavior-modifying practices that reduce insect host finding and acceptance.
- Developing more accurate knowledge about the relationship between crop losses and insect abundance so that forest managers know precisely when it is necessary to suppress insects.
- Maximizing the activities of all those beneficial insects that contribute positively to the vital process of forest ecosystems.